

# Scalar Field Reconstruction of Power-Law Entropy-Corrected HDE

Esmail Ebrahimi<sup>1,2</sup> \* and Ahmad Sheykhi<sup>2,3</sup> †

<sup>1</sup>*Department of Physics, Shahid Bahonar University, PO Box 76175, Kerman, Iran*

<sup>2</sup>*Research Institute for Astronomy and Astrophysics of Maragha (RIAAM), Maragha, Iran*

<sup>3</sup>*Physics Department and Biruni Observatory, Shiraz University, Shiraz 71454, Iran*

## Abstract

A so called “power-law entropy-corrected holographic dark energy” (PLECHDE) was recently proposed to explain the dark energy dominated universe. This model is based on the power-law corrections to black hole entropy which appear in dealing with the entanglement of quantum fields between inside and outside of the horizon. In this paper, we suggest a correspondence between interacting PLECHDE and tachyon, quintessence, K-essence and dilaton scalar field models of dark energy in a non-flat FRW universe. Then, we reconstruct the potential terms accordingly, and present the dynamical equations which describe the evolution of the scalar field dark energy models.

---

\* ebrahimi@uk.ac.ir

† sheykhi@uk.ac.ir

## I. INTRODUCTION

One of the most dramatic field of research in theoretical physics, these days, is the investigation on the cause of an unpredicted phase of accelerated expansion in our universe. According to different cosmological observations, our universe is undergoing a phase of accelerated expansion which the cause of it has not been known yet [1–5]. A component which is responsible for this acceleration usually called dark energy (DE). Most of the observations confirm that the DE consists more than 70% of the energy content of our universe and the nature of such a component is still unknown [6]. The simplest candidate for DE is the cosmological constant which leads to  $w = -1$  [7]. Though, it suffers the so-called fine-tuning and cosmic coincidence problems [2]. However, observations detect a deviation from the models with constant equation of state (EoS) parameter and show an evolution in the EoS parameter. Due to this fact another category of models has been proposed as possible candidates for DE. In these models the DE candidate has a dynamical behavior and lead to a variable EoS parameter. The simplest candidate in the dynamic approach is the scalar field  $\phi$ . This approach for probing the nature of DE has been extensively studied in the literature. Some famous examples of these models are quintessence, tachyon, K-essence, dilaton field and so on (see [8–11] and references therein). For a recent review on DE models see [12].

Among various attempts toward understanding the DE puzzle, the holographic dark energy (HDE) model has got a lot of enthusiasm recently. This model, which has been widely studied in the literature [13–24], is motivated from the holographic hypothesis [25] and has been tested and constrained by various astronomical observations [26, 27]. It is important to note that in the derivation of HDE density the black hole entropy  $S$  plays a crucial role. Indeed, the definition and derivation of holographic energy density ( $\rho_D = 3c^2 M_p^2 / L^2$ ) depends on the entropy-area relation  $S \propto A \propto L^2$  of black holes, where  $A$  represents the area of the horizon [13]. However, quantum corrections to the area law have been introduced in recent years, namely, logarithmic and power-law corrections. Logarithmic corrections, arises from loop quantum gravity due to thermal equilibrium fluctuations and quantum fluctuations [28],

$$S = \frac{A}{4G} + \gamma \ln \frac{A}{4G} + \delta, \quad (1)$$

where  $\gamma$  and  $\delta$  are dimensionless constants of order unity. The exact values of these constants are not yet determined and still an open issue in quantum gravity. This logarithmic term also appears in a model of entropic cosmology which unifies the inflation and late time acceleration [29]. Another form of the correction to the area law, namely the power-law correction, appears

in dealing with the entanglement of quantum fields in and out the horizon. The entanglement entropy of the ground state obeys the Hawking area law. Only the excited state contributes to the correction, and more excitations produce more deviation from the area law [30] (also see [31] for a review on the origin of black hole entropy through entanglement). The power-law corrected entropy is written as [32, 33]

$$S = \frac{A}{4G} \left[ 1 - K_\alpha A^{1-\alpha/2} \right], \quad (2)$$

where  $\alpha$  is a dimensionless constant whose value is currently under debate, and

$$K_\alpha = \frac{\alpha(4\pi)^{\alpha/2-1}}{(4-\alpha)r_c^{2-\alpha}}. \quad (3)$$

Here  $r_c$  is the crossover scale. The second term in Eq. (2) can be regarded as a power-law correction to the area law, resulting from entanglement, when the wave-function of the field is chosen to be a superposition of ground state and excited state [32].

The HDE models with logarithmic correction have been explored in ample details [34]. Very recently, by taking into account the power-law correction to entropy, a so called “PLECHDE” was proposed by Sheykhi and Jamil [35]. It was shown that this model is capable to provide an accelerated expansion. Due to the variety of models in the literature, to explain the DE problem, it seems essential to develop a correspondence between different approaches clarifying the theoretical status of the current models. To this end, in this paper we would like to implement the correspondence between scalar field energy density and PLECHDE model. This connection allows us to reconstruct the potential as well as the dynamics of the scalar fields which describe the acceleration of the universe expansion.

This paper is outlined as follows. In the next section we establish the correspondence between PLECHDE and the tachyon field dark energy model. In section III, we study the quintessence dark energy model based on the interacting PLECHDE. Section IV consists the reconstruction procedure of the K-essence PLECHDE. In section V, we consider the reconstructed model of the dilatonic DE based on the PLECHDE. We finish the paper with some concluding remarks in section VI.

## II. TACHYON RECONSTRUCTION OF PLECHDE

The tachyon model of dark energy originates from string theory and seems to have interesting cosmological consequences. One of the interesting properties of a rolling tachyon is its EoS parameter which changes between  $-1$  to  $0$  [36]. This EoS parameter convinces people to consider

the tachyon scalar field as a candidate for DE. It was demonstrated that dark energy driven by tachyon decays to cold dark matter in the late accelerated universe and this phenomenon yields a solution to cosmic coincidence problem [37]. Choosing different self-interacting potentials in the tachyon field model lead to different consequences for the resulting DE model. Due to this fact we would like to reconstruct the tachyon equivalent of the PLECHDE to see which tachyon scalar field model can demonstrate quantum gravity effects. The connection between tachyon field and HDE [38], agegraphic dark energy (ADE) [39], ECHDE [40] and ECADE models [41] have been already established. The effective lagrangian for the tachyon field is described by

$$L = -V(\phi)\sqrt{1 - g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi}, \quad (4)$$

where  $V(\phi)$  is the tachyon potential. The corresponding energy momentum tensor for the tachyon field can be written in a perfect fluid form

$$T_{\mu\nu} = (\rho_\phi + p_\phi)u_\mu u_\nu - p_\phi g_{\mu\nu}, \quad (5)$$

where  $\rho_\phi$  and  $p_\phi$  are, respectively, the energy density and pressure of the tachyon, and the velocity  $u_\mu$  is

$$u_\mu = \frac{\partial_\mu\phi}{\sqrt{\partial_\nu\phi\partial^\nu\phi}}. \quad (6)$$

We assume the background Friedmann-Robertson-Walker (FRW) metric which is described by the line element

$$ds^2 = dt^2 - a^2(t)\left(\frac{dr^2}{1 - kr^2} + r^2 d\Omega^2\right), \quad (7)$$

where  $a(t)$  is the scale factor,  $k$  is the curvature parameter with  $k = -1, 0, 1$  corresponding to open, flat, and closed universes, respectively. The first Friedmann equation takes the form

$$H^2 + \frac{k}{a^2} = \frac{1}{3M_p^2}(\rho_m + \rho_D), \quad (8)$$

where  $\rho_m$  and  $\rho_D$  are, respectively, the energy densities of pressureless matter and dark energy. The dimensionless density parameters are defined as usual

$$\Omega_m = \frac{\rho_m}{\rho_{cr}}, \quad \Omega_D = \frac{\rho_D}{\rho_{cr}}, \quad \Omega_k = \frac{k}{a^2 H^2}, \quad (9)$$

where the critical energy density is  $\rho_{cr} = 3H^2 M_p^2$ . Thus the first Friedmann equation can be rewritten as

$$1 + \Omega_k = \Omega_m + \Omega_D. \quad (10)$$

The energy density and pressure of tachyon field are given by

$$\rho_\phi = -T_0^0 = \frac{V(\phi)}{\sqrt{1 - \dot{\phi}^2}}, \quad (11)$$

$$p_\phi = T_i^i = -V(\phi)\sqrt{1 - \dot{\phi}^2}. \quad (12)$$

The equation of state parameter is

$$w_\phi = \frac{p_\phi}{\rho_\phi} = \dot{\phi}^2 - 1. \quad (13)$$

Following [35], we assume the energy density of the PLECHDE has the the following form

$$\rho_D = 3c^2 M_p^2 L^{-2} - \beta M_p^2 L^{-\alpha} = \frac{3c^2 M_p^2}{L^2} \gamma_c, \quad (14)$$

where

$$\gamma_c = 1 - \frac{\beta}{3c^2 L^{\alpha-2}}, \quad (15)$$

and  $L$  is a length scale which provides an IR cut-off for the holographic model of dark energy. In the literature a variety of IR cut-offs have been assumed. Li [14] discussed three choices for the length scale  $L$  which is supposed to provide an IR cut-off. The first choice is the Hubble radius,  $L = H^{-1}$  [16], which leads to a wrong equation of state, namely that for dust. The second option is the particle horizon radius. In this case it is impossible to obtain an accelerated expansion. Only the third choice, the identification of  $L$  with the radius of the future event horizon gives the desired result, namely a sufficiently negative EoS to obtain an accelerated universe. However, as soon as an interaction between dark energy and dark matter is taken into account, the identification of IR cut-off with Hubble (apparent horizon) radius can simultaneously drive accelerated expansion and solve the coincidence problem [17]. In recent years, some new infrared cut-offs have also been proposed in the literature. In [18] a HDE model with Ricci scalar as IR cut-off was proposed, while in [19] the authors have added the square of the Hubble parameter and its time derivative within the definition of HDE. A linear combination of particle horizon and the future event horizon was also proposed in [20]. In this paper, as system's IR cut-off, we take the radius of the event horizon measured on the sphere of the horizon defined as [21]

$$L = ar(t), \quad (16)$$

where  $r(t)$  can be obtained from

$$\int_0^{r(t)} \frac{dr}{\sqrt{1 - kr^2}} = \int_0^\infty \frac{dt}{a} = \frac{R_h}{a}. \quad (17)$$

Solving the above equation for  $r(t)$  we obtain

$$r(t) = \frac{1}{\sqrt{k}} \sin \left( \frac{\sqrt{k} R_h}{a} \right). \quad (18)$$

Here  $R_h$  is the radial size of the event horizon measured in the  $r$  direction. Assuming an interaction between dark energy and dark matter, the conservation equations read

$$\dot{\rho}_m + 3H\rho_m = Q, \quad (19)$$

$$\dot{\rho}_D + 3H\rho_D(1 + w_D) = -Q, \quad (20)$$

where  $Q = 3b^2 H(\rho_D + \rho_m)$  is an energy exchange term,  $b^2$  is a coupling constant and  $w_D$  is the EoS parameter of the DE component. Differentiating (14) with respect to cosmic time  $t$  and using (10), (16), (17) and (18) we have

$$\dot{\rho}_D = H\rho_D \left( \frac{\alpha - 2}{\gamma_c} - \alpha \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] \quad (21)$$

where  $y = \sqrt{k} \frac{R_h}{a}$ . Substituting the above relation in Eq. (20), we obtain [35]

$$w_D = -1 + \frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D}. \quad (22)$$

To develop the correspondence between PLECHDE and tachyon field, we identify  $w_D = w_\phi$  and obtain

$$\dot{\phi} = \sqrt{1 + w_D} = \sqrt{\frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D}}. \quad (23)$$

Using  $\dot{\phi} = \phi' H$ , we can write

$$\phi' = \frac{1}{H} \sqrt{\frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D}}, \quad (24)$$

where the prime denotes derivative with respect to  $x = \ln a$ . Integrating yields

$$\phi(a) - \phi(a_0) = \int_{a_0}^a \frac{1}{aH} \sqrt{\frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D}} da, \quad (25)$$

where  $a_0$  is the value of the scale factor at the present time  $t_0$ . Alternatively we can rewrite Eq. (25) as

$$\phi(t) - \phi(t_0) = \int_{t_0}^t \sqrt{\frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D}} dt'. \quad (26)$$

Also using relation (11), we have

$$V(\phi) = 3M_p^2 H^2 \Omega_D \sqrt{1 - \frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D}}. \quad (27)$$

Therefore, we have established an interacting power-law entropy-corrected holographic tachyon dark energy model and reconstructed the potential and the dynamics of the tachyon field. Such a tachyon scalar field model with potential (27) and dynamical equation (26) can act the role of DE as the PLECHDE.

### III. QUINTESSENCE RECONSTRUCTION OF PLECHDE

We use the term “quintessence” to denote a canonical scalar field  $\phi$  with a potential  $V(\phi)$  that can interact with all other components only through standard gravity. The quintessence model is therefore described by the lagrangian

$$\mathcal{L} = -\frac{1}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - V(\phi). \quad (28)$$

The energy-momentum tensor of quintessence is

$$T_{\mu\nu} = \partial_\mu \phi \partial_\nu \phi - g_{\mu\nu} \left[ \frac{1}{2} g^{\alpha\beta} \partial_\alpha \phi \partial_\beta \phi + V(\phi) \right]. \quad (29)$$

In the FRW framework the energy density and pressure of the quintessence field can be written as

$$\rho_\phi = -T_0^0 = \frac{1}{2} \dot{\phi}^2 + V(\phi), \quad (30)$$

$$p_\phi = T_i^i = \frac{1}{2} \dot{\phi}^2 - V(\phi), \quad (31)$$

where  $\rho_\phi$  and  $p_\phi$  denote the energy density and pressure, respectively. Using the above relations it can be easily seen that the kinetic term and the scalar potential are

$$\dot{\phi}^2 = (1 + w_D) \rho_\phi, \quad (32)$$

$$V(\phi) = \frac{1 - w_D}{2} \rho_\phi, \quad (33)$$

where  $w_D = p_\phi / \rho_\phi$ . Identifying  $\rho_\phi = \rho_D = \frac{3c^2 M_p^2}{L^2} \gamma_c$  and using (32) one obtains

$$\dot{\phi}^2 = 3M_p^2 H^2 \Omega_D \left( \frac{1}{3} \left( \alpha - \frac{\alpha - 2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1 + \Omega_k)}{\Omega_D} \right). \quad (34)$$

Using,  $\dot{\phi} = \phi' H$ , we have

$$\phi(a) - \phi(a_0) = \int_{\ln a_0}^{\ln a} \left( 3M_p^2 \Omega_D \left( \frac{1}{3} \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{b^2(1+\Omega_k)}{\Omega_D} \right) \right)^{1/2} d \ln a, \quad (35)$$

where  $a_0$  denotes the present value of the scale factor. From Eq. (32) the scalar potential is obtained as

$$V(\phi) = 3M_p^2 H^2 \Omega_D \left( 1 - \frac{1}{6} \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] + \frac{b^2(1+\Omega_k)}{2\Omega_D} \right).$$

One can easily check that the usual holographic quintessence dark energy model can be retrieved in the limiting case  $\gamma_c = 1 (\alpha = \beta = 0)$ .

#### IV. K-ESSENCE RECONSTRUCTION OF PLECHDE

Quintessence relies on the potential energy of scalar field which leads to the late time acceleration. It is possible to have a situation where the accelerated expansion arises out of modifications to the kinetic energy of the scalar field. K-essence is characterized by a scalar field with a non-canonical kinetic energy. The most general scalar-field action which is a function of  $\phi$  and  $X = -\dot{\phi}^2/2$  is given by [42]

$$S = \int d^4x \sqrt{-g} P(\phi, X), \quad (36)$$

where the lagrangian density  $P(\phi, X)$  corresponds to a pressure density. According to this lagrangian the energy density and the pressure can be written as [9]

$$\rho_\phi = f(\phi)(-X + 3X^2), \quad (37)$$

$$P_\phi = f(\phi)(-X + X^2). \quad (38)$$

Therefore the EoS parameter of the K-essence will be

$$w_K = \frac{P_\phi}{\rho_\phi} = \frac{1 - X}{1 - 3X}. \quad (39)$$

To implement the correspondence between K-essence and PLECHDE, we set  $w_K = w_D$  and solve (39) for  $X$ . We find

$$X = \frac{1 - w_D}{1 - 3w_D} = \frac{2 - \frac{1}{3} \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] + \frac{b^2(1+\Omega_k)}{\Omega_D}}{4 - \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] + \frac{3b^2(1+\Omega_k)}{\Omega_D}}. \quad (40)$$



Since  $\dot{\phi}^2 = -2X$  and  $\dot{\phi} = H\phi'$  we obtain

$$\phi(a) - \phi(a_0) = \int_{a_0}^a \frac{1}{Ha} \sqrt{\frac{-4 + \frac{2}{3} \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] - \frac{2b^2(1+\Omega_k)}{\Omega_D}}{4 - \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] + \frac{3b^2(1+\Omega_k)}{\Omega_D}}} da. \quad (41)$$

## V. DILATON FIELD RECONSTRUCTION OF PLECHDE

It is quite possible that gravity is not given by the Einstein action, at least at sufficiently high energy scales. The most promising alternative seems to be that offered by string theory, where the gravity becomes scalar-tensor in nature. In the low energy limit of the string theory, one recovers Einstein gravity along with a scalar dilaton field which is non-minimally coupled to gravity [43]. The dilaton field can be used for explanation the dark energy puzzle and avoids some quantum instabilities with respect to the phantom field models of DE [44]. The lagrangian density of the dilatonic dark energy corresponds to the pressure density of the scalar field has the following form [45]

$$P = -X + ce^{\lambda\phi} X^2, \quad (42)$$

where  $c$  and  $\lambda$  are positive constants and  $X = \dot{\phi}^2/2$ . Such a pressure (Lagrangian) leads to the following energy density [45]

$$\rho = -X + 3ce^{\lambda\phi} X^2. \quad (43)$$

The EoS parameter of the dilatonic DE can be written as

$$w = \frac{P}{\rho} = \frac{1 - ce^{\lambda\phi} X}{1 - 3ce^{\lambda\phi} X}. \quad (44)$$

Seeking for a correspondence between the dilatonic DE and PLECHDE we set  $w = w_D$ , where  $w_D$  comes from the PLECHDE. Solving this equation for  $cXe^{\lambda\phi}$  we obtain

$$cXe^{\lambda\phi} = \frac{w_D - 1}{3w_D - 1}. \quad (45)$$

Taking into account that  $X = \dot{\phi}^2/2$  we can rewrite Eq. (45) as

$$\frac{c}{2} \left( \frac{2}{\lambda} \frac{d}{dt} e^{\lambda\phi/2} \right)^2 = \frac{w_D - 1}{3w_D - 1}. \quad (46)$$

Using  $\frac{d}{dt} = H \frac{d}{d \ln a}$  leads

$$\phi(a) = \frac{2}{\lambda} \ln \left[ e^{\lambda\phi(a_0)/2} + \frac{\lambda}{\sqrt{2c}} \int_{\ln a_0}^{\ln a} \frac{1}{H} \left( \frac{w_D - 1}{3w_D - 1} \right)^{1/2} d \ln a \right], \quad (47)$$

which represents the evolution equation of  $\phi$ . Using the expression for  $w_D$  we can further rewrite the above equation as

$$\phi(a) = \frac{2}{\lambda} \ln \left[ e^{\lambda\phi(a_0)/2} + \frac{\lambda}{\sqrt{2c}} \int_{\ln a_0}^{\ln a} \frac{1}{H} \left( \frac{2 - \frac{1}{3} \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] + \frac{b^2(1+\Omega_k)}{\Omega_D}}{4 - \left( \alpha - \frac{\alpha-2}{\gamma_c} \right) \left[ 1 - \frac{1}{c} \sqrt{\frac{\Omega_D}{\gamma_c}} \cos y \right] + \frac{3b^2(1+\Omega_k)}{\Omega_D}} \right)^{1/2} d \ln a \right]. \quad (48)$$

## VI. CONCLUDING REMARKS

A possibility to explain the origin of the black hole entropy is the entanglement of quantum fields between in and out the horizon [32]. It was shown [32] that the black hole entropy is proportional to the horizon area when the field is in its ground state, while a correction term proportional to a fractional power of area results when the field is in a superposition of ground and excited states. For large horizon areas, these corrections are relatively small and the area law is recovered. Taking into account the correction to area law the HDE density is modified as well. Based on this, a so-called PLECHDE was proposed recently [35] to explain the acceleration of the cosmic expansion. On the other hand, there are many different models of DE in the context of a scalar field such as tachyon, quintessence, K-essence and dilaton fields. One exciting question is that whether a scalar field model can act as a dark energy model, while they have apparently distinct instinct. In this paper a connection between the scalar field models and the PLECHDE has established. As a result and using the proposal (14) we have reconstructed the potentials as well as the evolutionary forms of scalar fields. In section II we presented a tachyon field version of the PLECHDE. Then, we reconstructed the potential term and the dynamical equation governing the evolution of the tachyon field. In section III we established a correspondence between the PLECHDE and a quintessence model. The potential for the K-essence holographic correspondence was derived in section IV. We also considered the dilaton condensate without potential, and used the correspondence to find the evolutionary form of the scalar field. In the limiting case  $\gamma_c = 1$  ( $\alpha = 0 = \beta$ ), where the power-law correction becomes trivial, all our results reduce to their corresponding expressions in standard HDE scalar field models.

## Acknowledgments

This work has been supported financially by Research Institute for Astronomy and Astrophysics of Maragha, Iran.

- 
- [1] S. Perlmutter, et al., *Nature* 391 (1998) 51.
  - [2] A.G. Riess, et al., *Astron. J.* 116 (1998) 1009;  
A.G. Riess, et al., *Astron. J.* 117 (1999) 707.
  - [3] D.N. Spergel, et al., WMAP Collaboration, *Astrophys. J. Suppl.* 148 (2003) 175 ;  
D.N. Spergel, et al., astro-ph/0603449.
  - [4] M. Tegmark, et al., SDSS Collaboration, *Phys. Rev. D* 69 (2004) 103501.
  - [5] K. Abazajian, et al., SDSS Collaboration, *Astron. J.* 128 (2004) 502;  
K. Abazajian, et al., SDSS Collaboration, *Astron. J.* 129 (2005) 1755.
  - [6] T. R. Choudhury and T. Padmanabhan, *Astron. Astrophys.* 429, 807 (2005).
  - [7] V. Sahni and A. Starobinsky, *Int. J. Mod. Phys. D* 9, 373 (2000);  
P. J. Peebles and B. Ratra, *Rev. Mod. Phys.* 75, 559 (2003).
  - [8] C. Wetterich, *Nucl. Phys. B.* 302, 668 (1988).
  - [9] T. Chiba, T. Okabe and M. Yamaguchi, *Phys. Rev. D* 62, 023511 (2000).
  - [10] C. Armendariz-Picon, V. Mukhanov, and P. J. Steinhardt, *Phys. Rev. Lett.* 85, 4438 (2000).
  - [11] C. Armendariz-Picon, V. Mukhanov, and P. J. Steinhardt, *Phys. Rev. D* 63, 103510 (2001).
  - [12] E.J. Copeland, M. Sami, S. Tsujikawa, *Int. J. Mod. Phys. D* 15 (2006) 1753.
  - [13] A. Cohen, D. Kaplan, A. Nelson, *Phys. Rev. Lett.* 82 (1999) 4971.
  - [14] M. Li, *Phys. Lett. B* 603 (2004) 1.
  - [15] Q. G. Huang, M. Li, *JCAP* 0408 (2004) 013.
  - [16] S. D. H. Hsu, *Phys. Lett. B* 594 (2004) 13.
  - [17] D. Pavon, W. Zimdahl, *Phys. Lett. B* 628 (2005) 206;  
A. Sheykhi, *Class. Quantum. Gravit.* 27 (2010) 025007
  - [18] C. Gao, et al., *Phys. Rev. D* 79 (2009) 043511.
  - [19] L.N. Granda, *Phys. Lett. B* 669 (2008) 275;  
L.N. Granda and A. Oliveros, *Phys. Lett. B* 671 (2008) 199
  - [20] H.M. Sadjadi and M. Hoonardoost, *Phys. Lett. B* 647 (2007) 231.
  - [21] B. Wang, Y. Gong and E. Abdalla, *Phys. Lett. B* 624 (2005) 141.
  - [22] E. Elizalde, S. Nojiri, S.D. Odintsov, P. Wang, *Phys. Rev. D* 71 (2005) 103504;  
B. Guberina, R. Horvat, H. Stefancic, *JCAP* 0505 (2005) 001;  
B. Wang, E. Abdalla, R. K. Su, *Phys. Lett. B* 611 (2005) 21;

- H. Wei, Nucl. Phys. B 819 (2009) 210;  
 K. Karami, J. Fehri, Phys. Lett. B 684 (2010) 61;  
 K. Nozari, N. Rashidi, Int. J. Mod. Phys. D 19 (2010) 219.
- [23] B. Wang, C. Y. Lin and E. Abdalla, Phys. Lett. B 637 (2005) 357;  
 B. Wang, C. Y. Lin, D. Pavon and E. Abdalla, Phys. Lett. B 662 (2008) 1.
- [24] A. Sheykhi, Phys Lett B 681 (2009) 205;  
 A. Sheykhi, M. Jamil, Phys. Lett. B 694 (2011) 284.
- [25] G. t Hooft, gr-qc/9310026;  
 L. Susskind, J. Math. Phys. 36 (1995) 6377.
- [26] X. Zhang, F. Q. Wu, Phys. Rev. D 72 (2005) 043524;  
 X. Zhang, F. Q. Wu, Phys. Rev. D 76 (2007) 023502;  
 Q. G. Huang, Y.G. Gong, JCAP 0408 (2004) 006;  
 K. Enqvist, S. Hannestad, M. S. Sloth, JCAP 0502 (2005) 004.
- [27] B. Feng, X. Wang, X. Zhang, Phys. Lett. B 607 (2005) 35;  
 H.C. Kao, W.L. Lee, F.L. Lin, Phys. Rev. D 71 (2005) 123518;  
 J. Y. Shen, B. Wang, E. Abdalla, R. K. Su, Phys. Lett. B 609 (2005) 200.
- [28] K. A. Meissner, Class. Quantum Grav., 21 (2004) 5245;  
 A. Ghosh and P. Mitra, Phys. Rev. D, 71(2004) 027502;  
 A. Chatterjee and P. Majumdar, Phys. Rev. Lett. 92 (2004) 141301.
- [29] Y. F. Cai, J. Liu, H. Li, Phys. Lett. B 690 (2010) 213.
- [30] S. Das, S. Shankaranarayanan and S. Sur, arXiv:1002.1129.
- [31] S. Das, S. Shankaranarayanan and S. Sur, arXiv:0806.0402.
- [32] S. Das, S. Shankaranarayanan and S. Sur, Phys. Rev. D 77 (2008) 064013.
- [33] N. Radicella, D. Pavon, Phys. Lett. B 691 (2010) 121.
- [34] H. Wei, Commun. Theor. Phys. 52 (2009) 743;  
 M. Jamil, M.U. Farooq, JCAP 03 (2010) 001;  
 K. Karami, et al., Gen. Relativ. Grav. 43 (2011) 27, arXiv:1004.3607;  
 A. Sheykhi, et al., arXiv:1005.4541.
- [35] A. Sheykhi, M. Jamil, arXiv:1011.0134
- [36] G. W. Gibbons, Phys. Lett. B 537 (2002) 1.
- [37] S. K. Srivastava arXiv:gr-qc/0409074.
- [38] M. R. Setare, Phys. Lett. B 653 (2007) 116.
- [39] A. Sheykhi, Phys. Lett. B 682 (2010) 329;
- [40] A. Khodam-Mohammadi, M. Malekjani, arXiv:1004.1720
- [41] M. Jamil and A. Sheykhi, Int. J. Theor. Phys. 50 (2011) 625.
- [42] C. Armendariz-Picon, T. Damour, and V. F. Mukhanov, k-Inflation, Phys. Lett. B 458 (1999), 209.
- [43] M. B. Green, J. H. Schwarz and E. Witten, *Superstring Theory*, Cambridge University Press, Cambridge

(1987).

[44] S. M. Carroll, M. Hoffman and M. Trodden, Phys. Rev. D 68, 023509 (2003).

[45] F. Piazza and S. Tsujikawa, JCAP 0407, 004 (2004).